OPERATIONAL AMPLIFIER CARD

Model EU-900-NA

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EU-900-NA
595-1034-00
8-23-68

GENERAL INFORMATION

The several chassis modules and plug-in circuit cards in the Model EU-801 Analog-Digital Designer (ADD) make it a versatile system that is ideally suited for laboratory experiments in basic logic and digital operations, instrumentation, and computation. The ADD is equally well suited for the development and construction of a great variety of complex digital and analog devices, instruments, computer interfacing circuits, etc.

The chassis modules in the Model EU-801 provide the mounting frame, power connections, input/output circuitry, and controls for the plug-in circuit cards. The cards provide the functional circuitry for the operation to be performed, with a unique system of patch-wire interconnection between cards and modules.

TEXT

The text "Digital Electronics For Scientists" by H. V. Malmstadt and C. A. Enke (W. A. Benjamin Inc. Publisher) includes many experiments and applications in digital electronics and instrumentation for which the Heath EU-800 Series equipment is ideally suited. Portions of some of the Manuals in this series are taken from this text with permission of the authors and publisher. These portions are indicated in the Manuals by ☆DES.

MODULE INSTALLATION

The most convenient location for any module in the Analog-Digital Designer will depend upon its type, application, and the length of the power connector cable. The Digital Power Module will usually occupy the left-hand position in a 3-module cabinet. The other modules can be transposed, used alone, or connected and operated outside of the cabinet.

To install the module in a 3-module cabinet, slide the module into position from the front of the cabinet as shown below. Push firmly on the module until the spring catch on its chassis snaps onto the catch pin on the base of the cabinet.

Power connections between the modules in the ADD are made with 6-pin connectors and cables, at the rear of each module. Plug the male cable connector from each module except the Digital Power Module into the female chassis connector on the module to its left. The 6-pin cable connectors will transfer power from module to module.

When the installation and interconnection of the modules is complete, they may be secured in the cabinet with the 8-32 thumbscrews on the underside of the cabinet.

CIRCUIT CARD INSTALLATION

Any circuit card can be installed in virtually any card location in any module, except the Digital Power Module, and only the cards necessary for a given function need to be installed. The physical location of a card in the ADD will generally depend on convenience and the desirability of using short patch wires. If a circuit card should require an occasional adjustment, refer to the Adjustment section of the card Manual.

To install a card at a selected location, slide the ends of its circuit board into the front and rear guides in the module; then press the card firmly into place. Be sure the power connectors on the card fit onto the connector pins in the Module.

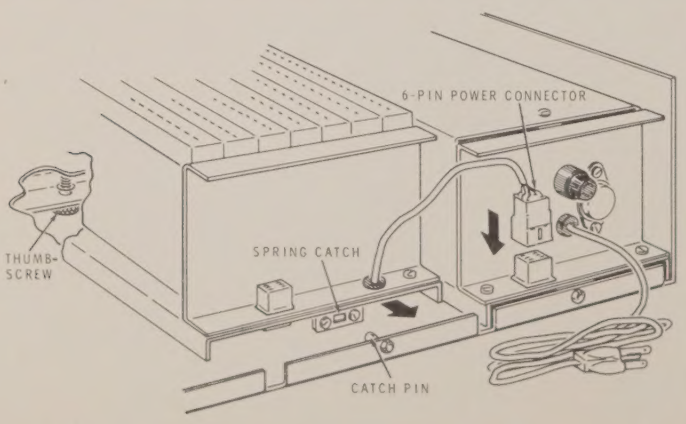
CONNECTIONS

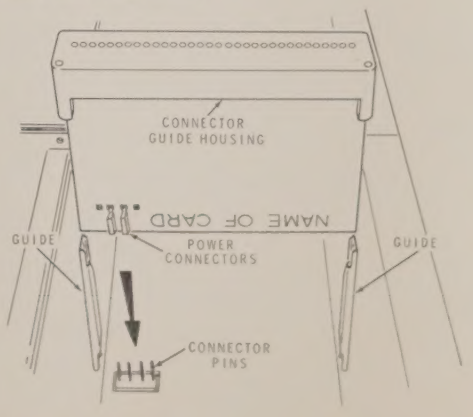
Connections between cards and modules in a Model EU-801 Analog-Digital Designer are made quickly and inexpensively with lengths of standard #22 solid hookup wire. The bare ends of the hookup wires are inserted into the appropriate connectors in the connector guide housing. Components such as resistors and capacitors can also be used between connectors where circuits require their use, providing the component leads are not larger in diameter than #22 gauge. Do not insert more than one wire or component lead in a connector at one time.

Patch wire may be prepared from lengths of #22 solid hookup wire. Cut the wires to the desired lengths and remove 1/2" of insulation from the ends. Do not use wire that is larger in diameter than #22 gauge (.025 inch).

The face of the connector guide housing is clearly labeled to indicate the circuit point for each connector. Groups of connectors tied to a common circuit point are indicated on the card label by joined lines. When more than one connection must be made to a single point, use one of the Multiple Connector Cards that are provided in the Model EU-801 ADD.

CAUTION: Transistors and integrated circuits can be damaged by excess voltage. The input signal to any digital circuit card must be within the range of 0 to +5 volts unless the card Manual indicates otherwise.





CARD INSTALLATION IN AN EU-801 SERIES MODULE

THE HEATH

OPERATIONAL AMPLIFIER CARD

Model EU-900-NA

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HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

EU-900-NA

INTRODUCTION

The Model EU-900-NA Operational Amplifier Card contains a high quality general-purpose operational amplifier and an independent logic driving amplifier. The operational amplifier has a permanently connected high-resolution balance potentiometer and four precision resistors permanently connected to the summing point. These four resistors, of which two are 10 kΩ and two are 100 kΩ, have their free ends brought to the patch-wire connectors for convenient use as input or feedback elements. The transistor logic driving amplifier is included to interface the operational amplifier output level to a TTL (transistor-transistor-logic) or DTL (diode-transistor-logic) input.

The operational amplifier is the basic circuit element in analog computation, analog control, analog-to-digital conversion, and digital-to-analog conversion circuits. In combination with passive components, it is used in analog adding, subtracting, integrating, differentiating, controlled voltage or current sources, sweeping, comparison circuits, and many others. With the logic and relay cards in the Analog-Digital Designer, it can be used for analog-to-digital and digital-to-analog conversion circuits, input level discriminator circuits, sample and hold amplifiers, etc.

The high input impedance, low input current and voltage drifts, high speed, gain, and common mode rejection make this Operational Amplifier Card desirable for a wide variety of analog circuit applications.

SPECIFICATIONS

OPERATIONAL AMPLIFIER

DC Voltage Gain, Open Loop	100 dB typical, at 10 kΩ load. 90 dB typical, 86 dB minimum at 5 kΩ rated load.
Frequency For Full Output	13 kHz typical, 10 kHz minimum. ($A = -1$, $R_{in} = R_f = 100\ k\Omega$, $R_L = 5\ k\Omega$)
Frequency For Unity Gain	1.2 MHz typical, 1 MHz minimum.
Slewing Rate	0.8 V/μs typical, 0.6 V/μs minimum.
Peak Output Voltage	±11 volts to ±13 volts at rated 5 kΩ load.
Peak Output Current	±3.5 mA typical, ±2.2 mA minimum.
Differential Input Impedance	60 MΩ typical, 30 MΩ minimum.
Common Mode Input Impedance	1600 MΩ typical, 750 MΩ minimum.
Input Voltage Characteristics	Initial Offset: Adjustable to zero. Drift vs. temperature: 20 μV/degrees Celsius typical, 45 μV/degrees Celsius maximum. Drift vs. time: 50 μV/24 hr.

Input Current Characteristics, Either Input. . . Initial Offset: 3 nA typical, 6 nA maximum. Drift vs. temperature: 0.15 nA/degrees Celsius typical, 0.3 nA/degrees Celsius maximum. Drift vs. time: .5 nA/24 hr. typical, 1 nA/24 hr. maximum.

Input Current Characteristics, Differential. . . Initial Offset: 1.5 nA typical, 6 nA maximum. Drift vs. temperature: .1 nA/degrees Celsius typical.

Broadband Input Noise. . . . . 15 μ Vrms, typical, 30 μV maximum to 10 kHz. (A = -100, R_f = 100 kΩ, R_{in} = 1 kΩ, R_L = 5 kΩ)

Common Mode Voltage Peaks. . . . . ±10 volts maximum.

Common Mode Rejection Ratio. . . . . 110 dB typical.

TRANSISTOR LOGIC DRIVER

Input Signal. . . . . ±15 volts maximum.

Input Impedance. . . . . Greater than 5000 ohms.

Input/Output Voltage And Impedance. . . . . .

INPUT	OUTPUT		
VOLTAGE	LOGIC LEVEL	VOLTAGE	IMPEDANCE
> 0.8	0	0.2	≃0 Ω
< 0.7	1	5.0	≃500 Ω

Approximate Fan-out (load units). . . . . 10 maximum.

POWER REQUIREMENTS

Operational Amplifier

Voltage. . . . . ±15 volts DC.
Quiescent Current. . . . . 6.5 mA maximum.
Full Load Peak Current. . . . . 8.8 mA maximum.
Short Circuit Current. . . . . 12 mA maximum.

Transistor Logic Driver

Voltage. . . . . +5 volts DC.
Current. . . . . 10 mA maximum.

CAUTION: The output voltages of the operational amplifier at connectors 6 through 9 can destroy the 5 volt logic circuits on other circuit cards. Always connect this output voltage through the transistor logic driver circuit unless your other circuits are specifically rated to ±15 volts.

OPERATION

When used with appropriate input circuits, feedback circuits and components, the operational amplifier can be used in a countless number of applications. The 5 volt logic driver included on this Card provides interfacing for added versatility in the Analog-Digital Designer and hybrid instrument applications. Some typical examples of the many uses of this Card are presented in the Applications section of this Manual.

Connections to the circuits on this Card are made to the card-top connectors, which accept patch wires or component leads. The card circuits and connections are clearly identified by the label on the face of the connector guide, as shown in Figure 1. The inclusion of four frequently-used precision resistors facilitates convenient patching of commonly used operational amplifier circuits. Multiple input and output connectors are provided for applying more than one source or load. An isolated 4-connector strip, [connectors (23) to (26)], provides a tie point for connecting three additional patch wires to a common point.

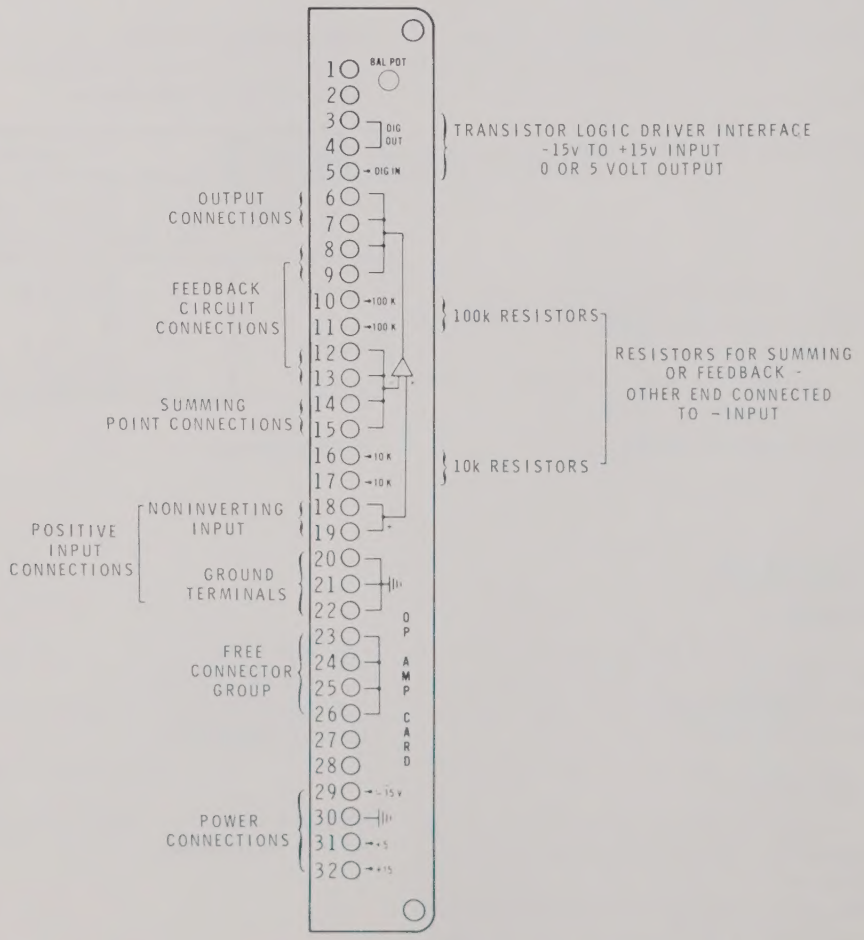
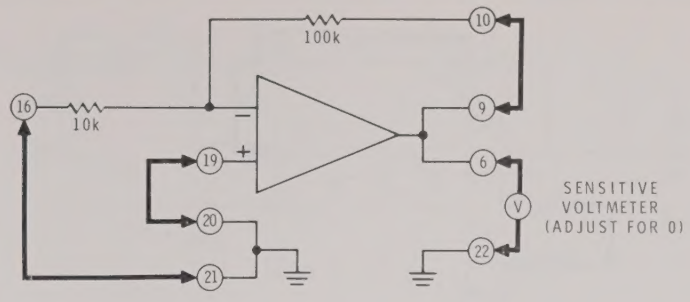


Figure 1



ZERO ADJUSTMENT CIRCUIT
Figure 2

Power requirements for this Card are +15 and -15 volts for the operational amplifier, and +5 volts for the logic interfacing circuit. This power is automatically connected when the Card is installed in an Analog-Digital Designer, or the power can be applied through patch wires to connectors at the top or bottom of the Card.

The operational amplifier has a Balance, or zero, adjustment so a 0 volt output can be obtained when there is no potential difference between the + and - inputs. To easily check the balance adjustment, wire the circuit shown in Figure 2. The internal resistors are used to make a gain-of-ten amplifier which amplifies the input offset voltage ten-fold and provides a more sensitive zero balance adjustment. Use a voltmeter that is sensitive to 1 millivolt or less, and adjust the Balance control for a zero output voltage.

The output voltage of the operational amplifier connectors (6) through (9) can destroy the 5-volt logic circuits on other circuit cards if directly connected to them. The logic driver digital interface circuit on this Card will accept any voltage between +15 volts and -15 volts, and its output level will be either 0 or +5 volts. An input voltage to the logic driver of more than 0.8 volt provides a logic 0 output, while an input of less than about 0.7 volt provides a logic 1 output. Use this interface circuit for connecting operational amplifier output signals to any DTL or TTL logic circuit inputs.

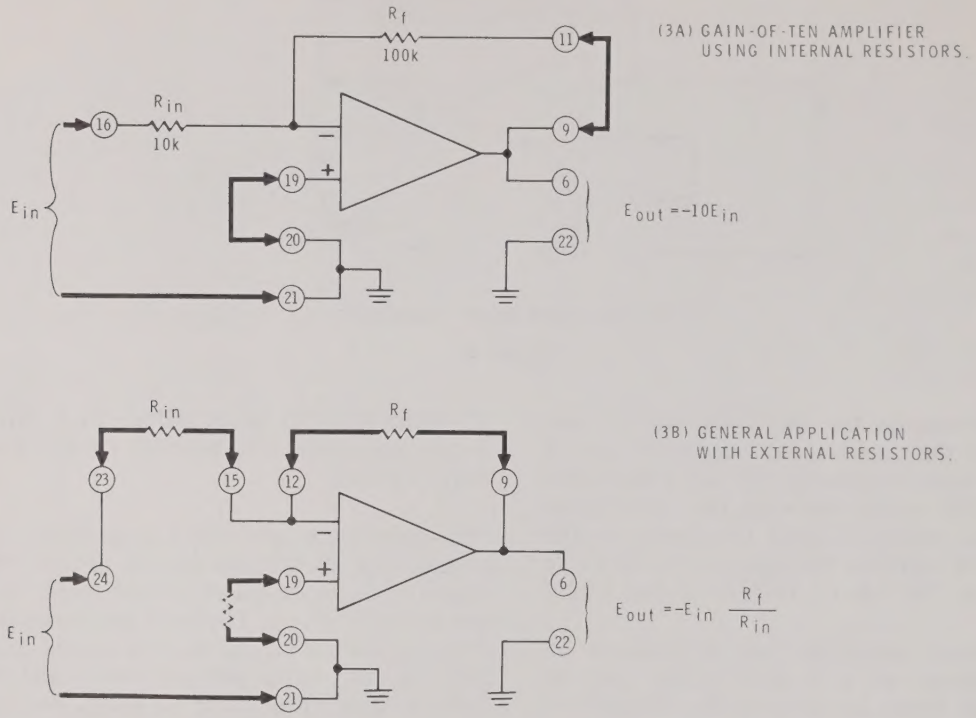
APPLICATIONS

Operational amplifier applications fall generally into four categories. These are: amplification, generation, computation, and sensing. Some representative applications in each of these areas are given in the following paragraphs.

AMPLIFICATION

The operational amplifier is a differential amplifier with a voltage gain of about 100,000 and an output voltage range of ±10 volts. This means that only 100 microvolts difference in potential between its two inputs will provide full output voltage. The amplifier is generally used with degenerative or negative feedback to provide greater gain stability, less distortion, less noise, higher input impedance, or other special characteristics. If a feedback circuit is used, and if the output voltage is within its maximum voltage and current ratings, the difference in potential between the two inputs must be less than 100 microvolts. For many applications, this difference is essentially zero.

The minus (-) and (+) inputs of the operational amplifier are called inverting and noninverting respectively, since a positive signal change at the inverting (-) input will cause a negative change at the output; but the direction of change is the same at the noninverting (+) input and output. Negative feedback circuits apply a fraction of the output change to the input so as to reduce the input voltage change. A feedback resistor is generally connected between the output and the inverting (-) input since the direction of signal change at these two points is opposite.



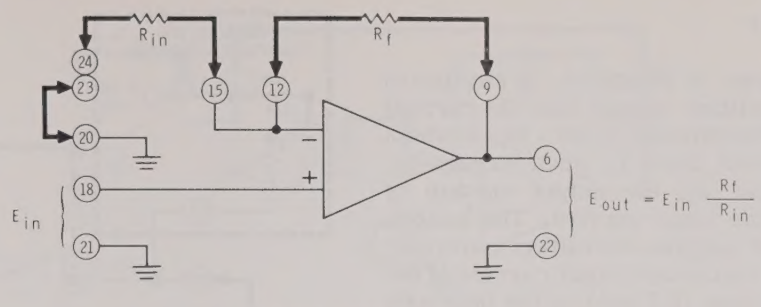
INVERTING AMPLIFIER

Figure 3

Inverting Amplifier

An inverting amplifier circuit is shown in Figure 3. Figure 3A shows a gain-of-ten amplifier using the internal resistors, while Figure 3B is a general applications amplifier using external resistors. In these circuits, resistor R_f provides negative feedback. Since the + input is grounded, the - input is a virtual ground (very near ground potential). The current I_{in} through R_{in} is E_{in}/R_{in}. Assuming that the - input of the operational amplifier itself requires negligible current (approximately 3 nanoamperes), the current through R_f is the same. Therefore, $E_{out} = -I_n R_f = -E_{in} (R_f/R_{in})$. The - sign indicates the polarity inversion, and the ratio R_f/R_{in} determines the gain.

For a low gain application, the gain accuracy is determined by the accuracy of R_f and R_{in}. A gain of 1000 with one percent accuracy can be achieved before the amplifier characteristics limit the accuracy. The input impedance is R_{in} and the output impedance is a few ohms or less. The maximum sensitivity is limited only by the input voltage and the current drift and noise specifications. To minimize voltage offset due to input current when R_{in} is very large, a resistor equal to R_{in} can be used to connect the + input (19) to ground.



NON-INVERTING AMPLIFIER

Figure 4

Noninverting Amplifier

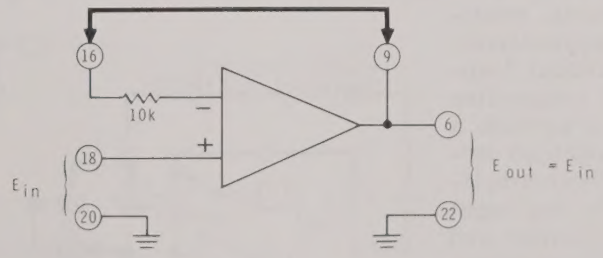
Figure 4 shows a simple variation on the inverting amplifier. The + input is at the potential E_{in}, and the - input must therefore be at this same potential. The potential of the - input can also be obtained by considering R_f and R_{in} as a voltage divider from the output to ground. Thus

$$E_{in} = E_{out} \cdot \frac{R_{in}}{R_f + R_{in}} \quad \text{and} \quad E_{out} = E_{in}(R_f + R_{in})/R_{in}$$

A potentiometer can be used for R_f or R_{in} (or both, if the wiper is connected to the - input) for an adjustable gain amplifier. This amplifier has the advantage of a very high input impedance (approximately 60 megohms with approximately 3 nanoamperes of input current).

Follower Amplifier

The follower amplifier shown in Figure 5 is a variation of the noninverting amplifier. In this case, the output is either directly connected to the - input, or connected through a small resistor. (The current is so small that the IR drop is negligible.) The + input is connected to E_{in}. Since $E_{-in} = E_{+in}$, and $E_{out} = E_{-in}$, $E_{out} = E_{in}$. This amplifier is used for impedance matching applications since it has a very high input impedance, an extremely low output impedance, and good response speed. It can be used for increasing the input impedance of measurement devices such as oscilloscopes, recorders, and digital voltmeters; or for reducing the output impedance of voltage sources such as standard cells, voltage reference sources, and the like.

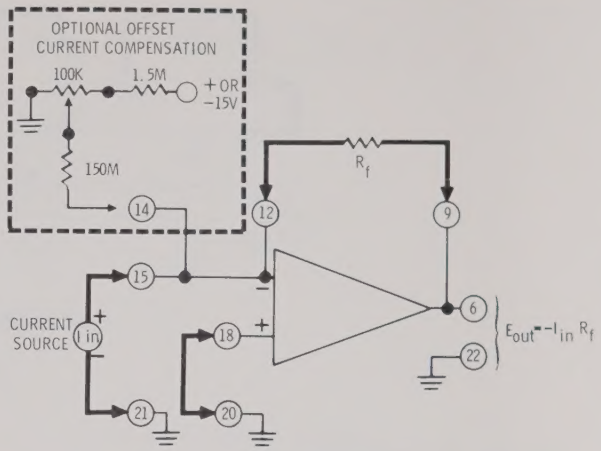


FOLLOWER AMPLIFIER

Figure 5

Current Amplifier

This circuit, shown in Figure 6, is similar to the inverting amplifier except that the current source is connected directly to the - input, which is at virtual ground. Since I_{in} goes through R_f, $E_{out} = -I_n R_f$; that is, the output voltage is proportional to the input current. The usable input range of this current-to-voltage converter is limited by the maximum output current of the operational amplifier (2.2 mA) on the high side and the amplifier input current on the low side. A current of 1 microampere would yield a full-scale output of 10 volts with R_f = 10M. With an amplifier input current of 3 nanoamperes, the error would be 0.3 percent. An adjustable nanoampere current source could be connected as shown to compensate for the input current, which would reduce the error or increase the sensitivity ten-fold.



CURRENT AMPLIFIER

Figure 6

Logarithmic Or Nonlinear Amplifier

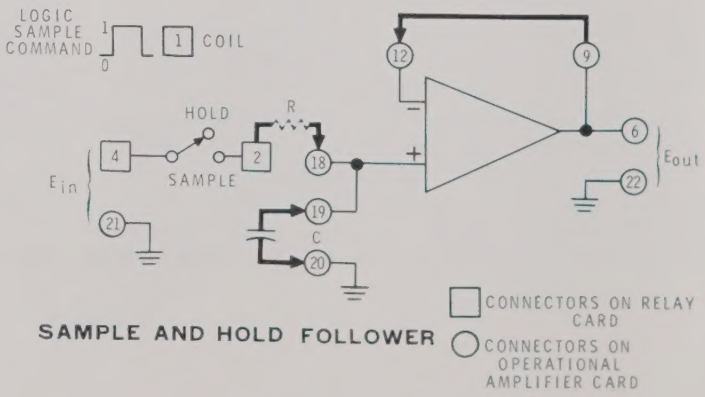
A logarithmic or other nonlinear amplifier can be made by using a log-diode or other device with a nonlinear current-voltage curve in place of R_f in Figure 6 or Figure 3.

Sample And Hold Follower

By combining a switching circuit, a capacitor, and an operational amplifier, circuits can be constructed which will measure a signal voltage at a particular time (sample), and then retain that output voltage (hold) for a given interval. Such circuits are used in analog-to-digital converters, sampling devices, multiplexers, and similar applications. In Figure 7, the Operational Amplifier Card is used in conjunction with the Relay Card to provide a logic-actuated sample and hold circuit. This is the follower amplifier which responds to the input signal in the sample position and then, when the relay opens, measures the last signal value which is held on capacitor C. The minimum sampling time (charging rate) is determined by the time constant, RC. The maximum holding time is determined by capacitor C, amplifier input current, and the desired holding accuracy.

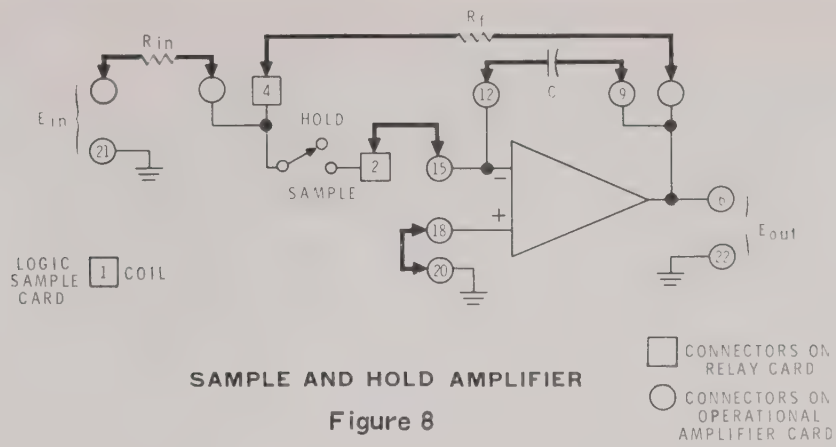
Sample And Hold Amplifier

A different arrangement is used in Figure 8 to provide some possible amplification as well. In the sample mode, the circuit is the inverting amplifier of Figure 1 with C in parallel with R_f. When E_{in} is changed, the voltage across C (the output voltage) comes to a steady value at a rate determined by R_{in}, R_f, and C. In the hold mode, the output is held by C.



SAMPLE AND HOLD FOLLOWER

Figure 7



SAMPLE AND HOLD AMPLIFIER

Figure 8

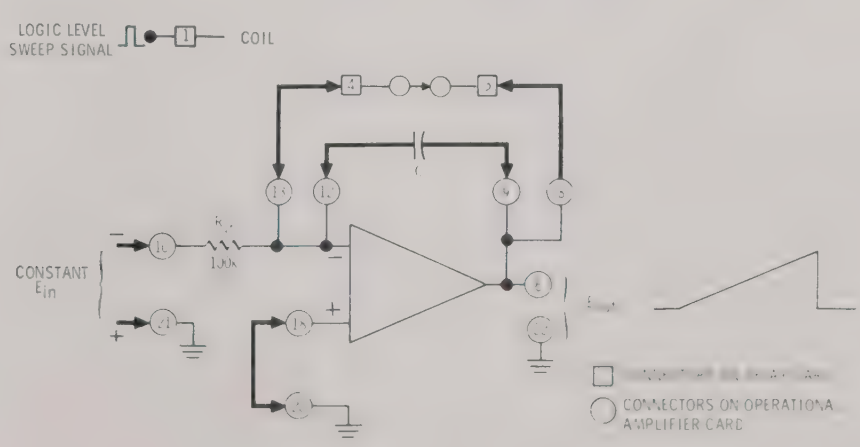
GENERATION

Controlled Current And Voltage Sources

A controlled voltage source with low output impedance can be made by using an amplifier circuit with a reference voltage signal source. The non-inverting amplifier that was shown in Figure 4 is a particularly convenient circuit for this application. Since the potential at the input is E_{in}, E_{out} is controlled at $-\frac{R_f}{R_{in}} \cdot E_{in}$, and the current through R_f is controlled at E_{in}/R_{in}. Connecting the load at E_{out} makes this a variable output voltage generator. The load may be both R_f and R_{in} where the voltage across R_{in} is to be constant and R_f is some unavoidable variable resistance. The - input connection then serves as a "remote sensing" connection to keep the potential across R_{in} equal to E_{in}. If the load is R_f and R_{in} is fixed, the current through R_f is fixed at E_{in}/R_{in} in because the potential across R_{in} is fixed.

Sweep Generator

A sweep generator may be made by using a capacitor for the feedback circuit as shown in Figure 9. The current through R_{in} is constant (E_{in}/R_{in}). When the switch is opened, this constant current is accumulated on C, causing it to charge at a constant rate. This results in a linear ramp or sweep signal at the amplifier output. By closing the switch, the ramp is terminated. By alternately reversing E_{in}, a triangular waveform could be generated.



SWEEP GENERATOR

Figure 9

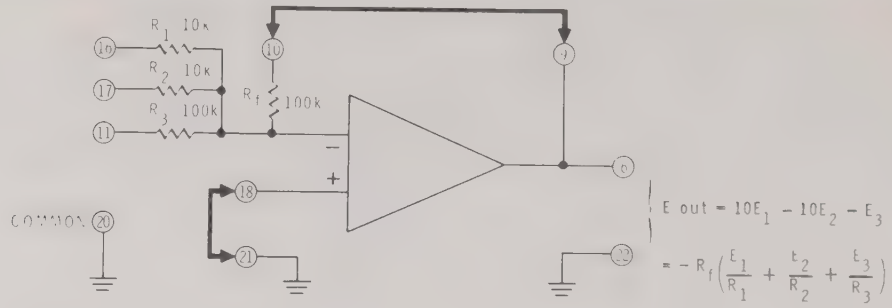


Figure 10

COMPUTATION

Sum And Difference

By connecting more than one input signal and resistor to the - input of an inverting amplifier (Figure 3), a summing amplifier results, as shown in Figure 10. The current from each input goes through R_f and adds to the output voltage. A difference or subtracting circuit can be made by inverting one of the inputs or by using the + input as in Figure 11.

Integration

The sweep generator shown in Figure 9 is also an integrator circuit. When the switch is opened, a current flow proportional to the input voltage accumulates on the capacitor. Thus, the output voltage is $-(\int_0^t I_{in}\,dt)/C$

and, therefore, $E_{out} = -\frac{\int_0^t E_{in}\,dt}{RC}$

and the time integral from 0 to t results. This circuit is used for measuring areas and for solving differential equations.

Differential Equations

To illustrate the application of operational amplifiers to solve differential equations, the simple problem of the falling body is illustrated below.* A mass, falling with no friction under

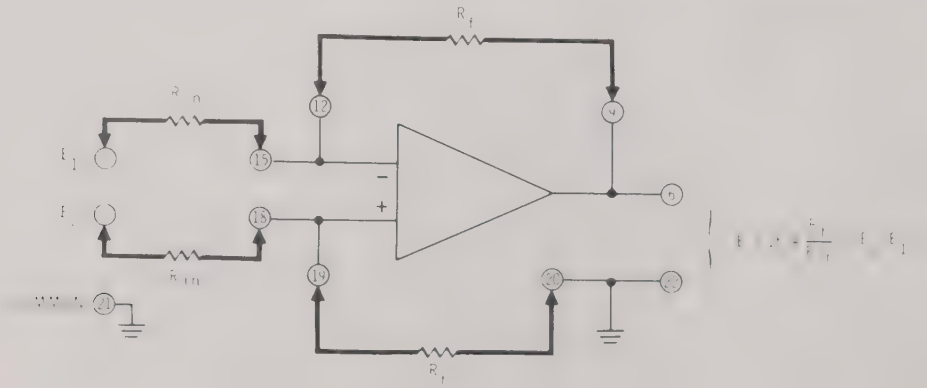


Figure 11

*from Electronics for Scientists - Malmstadt and Enke - W.A. Benjamin Inc. 1962.

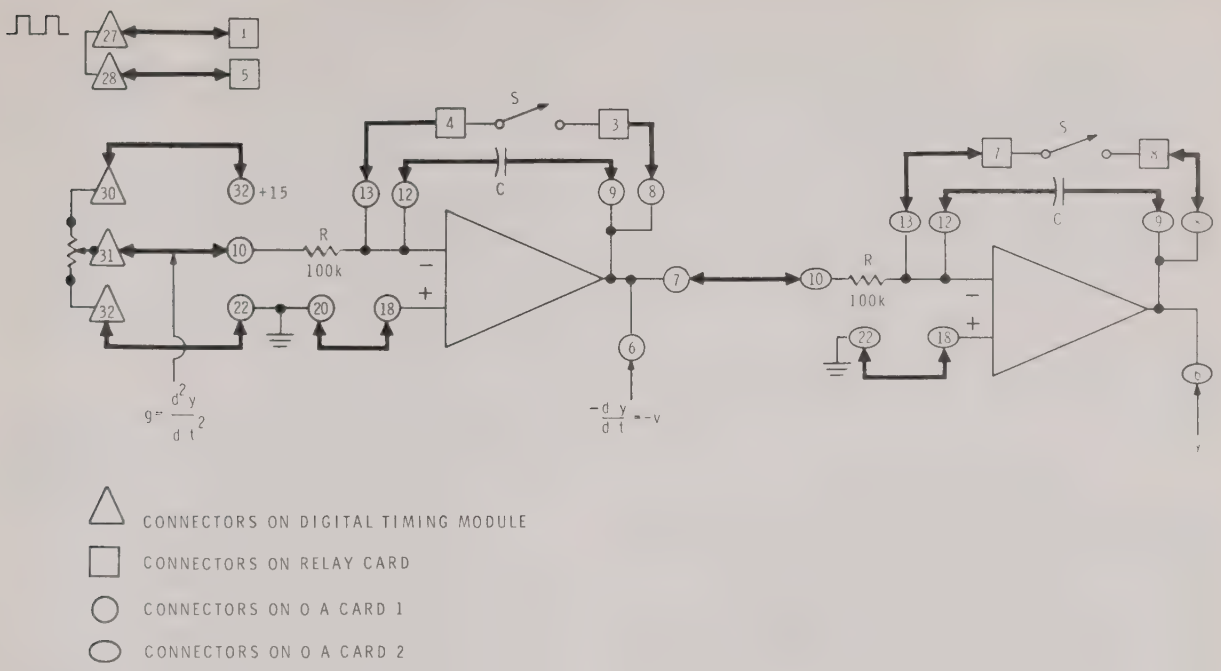


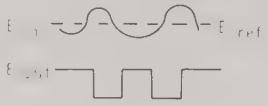
Figure 12

the influence of gravitational force g, obeys the equation $\frac{d^2y}{dt^2} = g$,

where y is the vertical position of the mass. To solve this equation for y, it is necessary to integrate twice. The circuit shown in Figure 12 requires two Operational Amplifier Cards and a Relay Card. The Relay Card is used to time the integration, with the relay coils driven by the Digital Timing Module to provide a repetitive solution.

The solution is obtained as follows: A voltage analogous to g is integrated to yield the negative of the first derivative of y, or the velocity. This quantity is integrated to yield the actual position (y) of the mass. Of course, the position of a mass falling free in a gravitational field is a function of time. The position-time relationship can be observed by plotting y as a function of time on a recorder or an oscilloscope.

The solution to the problem begins with the mass at rest (dy/dt = 0) at a reference position (y = 0). This is the situation when the switches S are closed. The integrations begin when both switches are opened and the mass begins to accelerate. If the time constant (RC) of the integrating circuit is 1 sec, e.g., 1 megohm X 1 μf, the observed time axis will correspond exactly to the time required for an actual fall. The integrator can operate on any time scale; however, if a quicker solution to the problem is desired, a shorter time constant can be used.



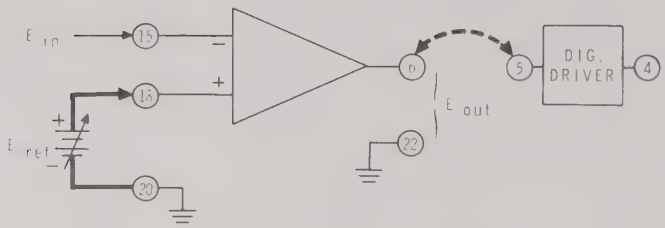


Figure 13

SENSING

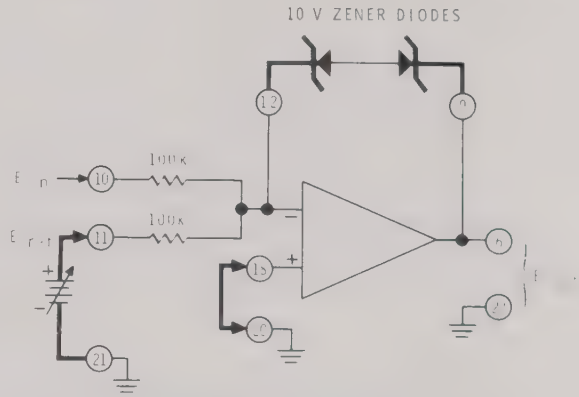
The entire gain of the operational amplifier is frequently used in sensing or comparator applications. The simplest circuit is shown in Figure 13. When $E_{in} > E_{ref}$, $E_{out} = -10\,V$; and when $E_{in} < E_{ref}$ $E_{out} \cong +10V$. If the Digital driver is used for interfacing to FFL, DTL, or relay circuits, the outputs from (4) are 0 and +5V respectively. This circuit drives the amplifier to saturation in both directions, which can be avoided by using zener diodes to catch the output before it limits, as in Figure 14. The summing configuration keeps the - input at virtual ground. Now

$E_{out} = +E_{zener}$ when $E_{in} < -E_{ref}$.

Occasionally, hysteresis is desired in a comparator to avoid triggering on the noise component of the signal more than once at each transition. This is accomplished as shown in Figure 15. A fraction of the output voltage is applied to the + input to increase the difference between the signal and trigger point immediately after the output transistion occurs. The larger the ratio, R_1/R_2, the larger the hysteresis and noise immunity. However, the hysteresis does make the trigger potential different for positive-going and negative-going signals.

Many other applications can be worked out along the lines illustrated by these examples. Further applications can also be found in the following books:

Applications Manual for Computing Amplifiers
Philbrick Researches, Inc.
Boston, Mass.



COMPARATOR WITH CATCHING DIODES.

Figure 14

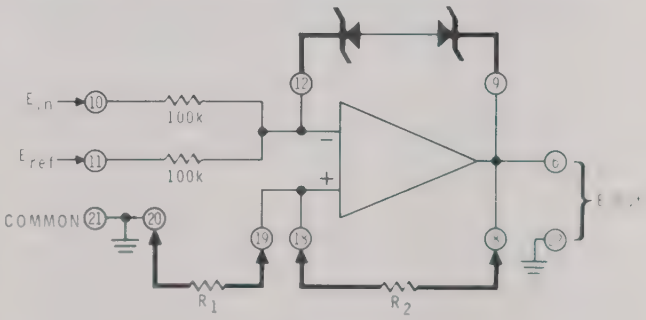


Figure 15

Linear Integrated Circuits Handbook
Fairchild Semiconductor
Mountain View, California

Handbook of Operational Amplifier Applications
Burr Brown Research Corp.
Tucson, Arizona

CIRCUIT DESCRIPTION

Two distinct electronic circuits are contained on the EU-900-NA Operational Amplifier Card. One circuit is a fully encapsulated operational amplifier module with a permanently-connected balance potentiometer and four resistors that are connected at one end to the summing point of the operational amplifier. The other circuit is a transistor voltage level converter that will provide a logic level (0 or 5 volt) output when an input voltage between -15 and +15 volts is applied.

The two circuits are completely independent of each other unless they are interconnected with patch wires. The Schematic Diagram shows the circuits and their terminals at the connector guide housing.

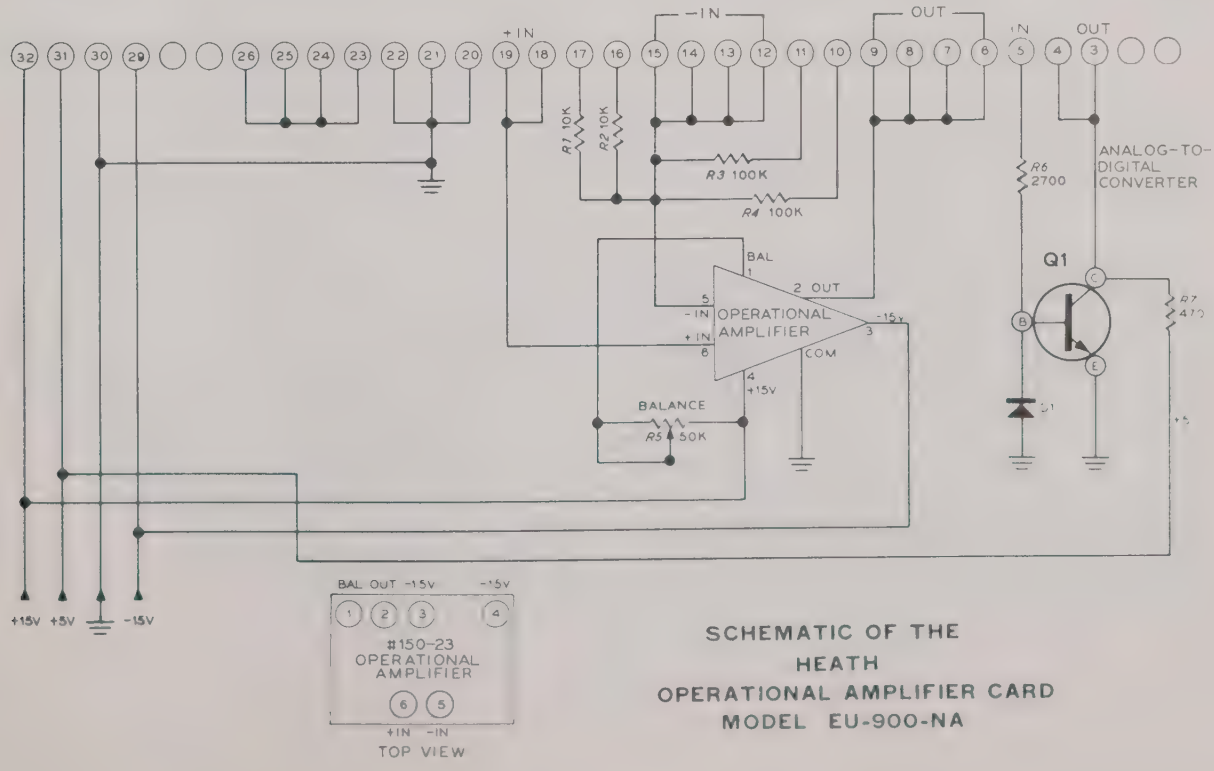
The operational amplifier is a differential amplifier that operates on the potential difference between its inverting (-) input and noninverting (+) input. With a voltage gain of approximately 100,000 an input voltage of only 100 microvolts will provide its full output of ±10 volts. The gain of the amplifier can be reduced by using feedback resistors.

Since the input impedance of the operational amplifier is very high and its output impedance extremely low, its gain can be controlled by the selection of an input/feedback resistor ratio. Two 10 kΩ and two 100 kΩ resistors are provided for this purpose, or external resistors of other values can be used. The gain of the operational amplifier will be equal to the ratio of the resistors used.

The balance potentiometer provides a zero adjustment that will make the output of the amplifier zero when no potential difference exists between its inputs.

The voltage level converter transistor circuit is used to restrict output levels between 0 and 5 volts. This circuit is convenient for interfacing the operational amplifier to other logic circuits, since the maximum output voltage of the amplifier could damage other logic circuits if connected directly.

Signals applied to the input of the transistor circuit pass through resistor R6 and are clipped



SCHEMATIC OF THE
HEATH
OPERATIONAL AMPLIFIER CARD
MODEL EU-900-NA

by diode D1 to prevent negative portions of the signal from being applied to the base of the transistor. Positive signals greater than approximately 0.8 volt cause the transistor to conduct and produce a logic 0 at the output while signals less than 0.7 volt provides a logic 1 at the output.

Connections for +5 volts, +15 volts, -15 volts, and ground, are made when the card is inserted in a module of the Analog-Digital Designer. These connections, as well as the inputs, outputs, and resistor connections, are brought to the terminals in the connector guide housing.

IN CASE OF DIFFICULTY

This section of the Manual will help you locate and repair minor difficulties that might arise in the operation of this circuit card.

General Troubleshooting describes a basic checkout procedure to identify common problems. Circuit Board Repair tells how to replace connectors and components, and how to repair a circuit board foil.

Electronic circuit troubleshooting requires special training and test equipment. If the information in this section of the Manual does not help you locate and repair the problem, do not attempt other repairs unless you have the technical skill and equipment.

GENERAL TROUBLESHOOTING

As the first step, make sure the card is properly seated in the Module or Instrument so the connectors fit snugly on the connector pins. If this card is used in a Module, double check the patch-wire connections.

Also check to see that a patch wire fits snugly into each connector. A connector may have become enlarged by inserting a wire larger than #22 or by inserting more than one wire at a time. A connector may also have been damaged by removal or replacement of the connector guide housing.

Visual inspection may reveal a damaged component or a break in the foil. If you find a burned-out part, such as a charred resistor, be sure to locate and correct the cause before you replace the part or put the equipment back into operation.

CIRCUIT BOARD REPAIR

The correct procedure for replacing integrated circuits, components, and connectors, and for repairing circuit board foils, is presented in the following paragraphs.

Integrated Circuits

Integrated circuits can be removed by first melting the solder at one pin at a time and removing the solder with a solder sipper or wire brush. Straighten each pin and remove the integrated circuit.

When you install a new integrated circuit, position it so its locating mark lines up with the locating mark on the circuit board; be sure all pins fit into the proper holes. Solder the pins quickly to avoid excessive heat. Begin by soldering pins at opposite corners and then pins on alternate sides of the integrated circuit.

Components

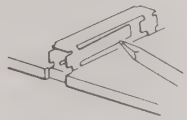
Faulty resistors or capacitors should first be clipped from the circuit board with diagonal cutters as shown. Remove the component leads from the circuit board by heating the solder on the foil side and allowing the lead to fall out of the hole.

Preshape the leads of the replacement part and insert them in the holes in the circuit board; the body of the part should be flush against the board. Then solder the leads to the foil and cut off the excess lead lengths.

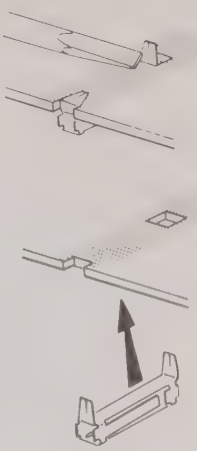
Transistors can be removed in the same manner as resistors or capacitors. The replacement transistor must be installed with its leads in the proper holes; then solder the leads quickly to avoid heat damage. Clip off the excess lead lengths.

Connectors

An enlarged connector can usually be repaired by bending in the spring contacts on its sides. Use a pointed tool as shown. Then test the contact by inserting the end of a #22 patch wire.



To replace a connector, melt and remove the solder from its mounting tabs as shown. Then pry the tabs away from the foil and remove the connector. Install the new connector at the same location with its open end toward the edge of the circuit board. Bend the mounting tabs over and solder them to the foil.



Foil Repair

A break in a circuit board foil can be soldered after first removing the solder-resist coating from the foil in the area of the break. Large gaps in a foil should be bridged with a short length of bare wire. Lay the bare wire across the gap and solder each end to the foil.

NOTE: Refer to Service Information inside the rear cover of this Manual for information on Factory Service, Technical Consultation, Replacement Parts, and Warranty.

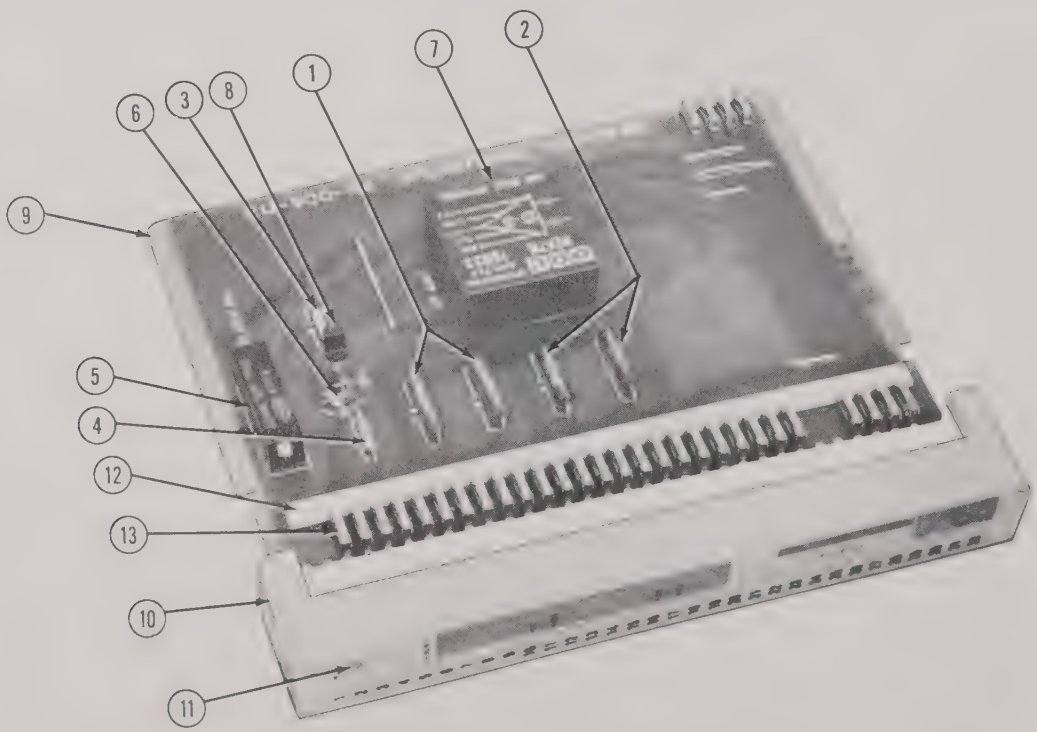
REPLACEMENT PARTS LIST

The numbers in parentheses are keyed to numbers on the Parts Pictorial.

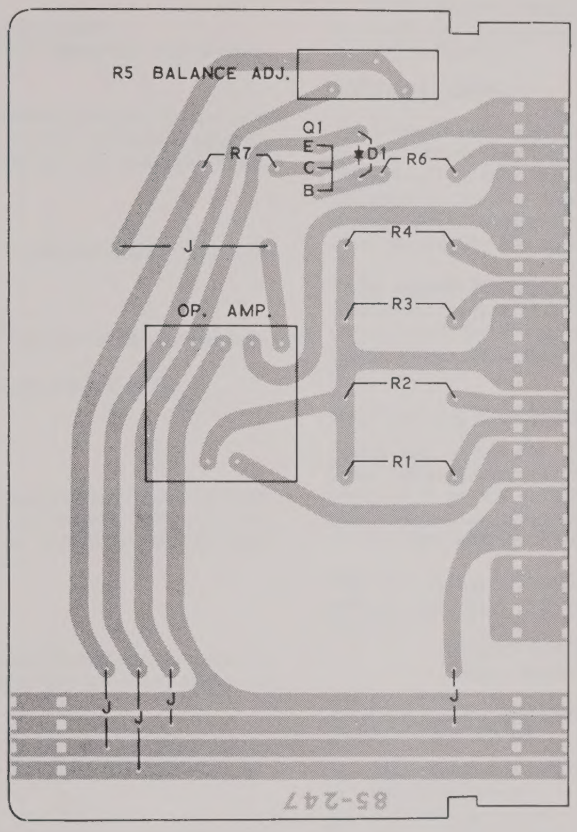
PART No.	PRICE Each	DESCRIPTION
(1) 2-11	.25	100 kΩ, 1/2 watt 1% resistor
(2) 2-50	.20	10 kΩ 1/2 watt 1% resistor
(3) 4-11-12	.10	470 Ω 1/4 watt 5% resistor
(4) 4-19-12	.10	2700 Ω 1/4 watt 5% resistor
(5) 11-95	4.20	50 kΩ 22-turn control
(6) 56-56	.20	1N4149 diode
(7) 150-23	44.00	Operational amplifier
(8) 417-118	.40	2N3393 transistor
(9) 85-247-1	3.65	Circuit board
(10) 214-47-2	.95	Connector guide housing
(11) 390-209	.20	Connector guide label
(12) 333-6	.15	Wire stop
(13) 432-77	.10	Connector
595-1034	-	Manual

The above prices apply only on purchases from the Heath Company where shipment is to a U.S.A. destination. Add 10% (minimum 25 cents) to the price when ordering from an authorized Service Center or Heathkit Electronic Center to cover local sales tax, postage and handling. Outside the U.S.A. parts and service are available from your local Heathkit source and will reflect additional transportation, taxes, duties and rates of exchange.

PARTS PICTORIAL



X-RAY VIEW



SERVICE INFORMATION

The following Heath Company services are available if you need them: Replacement Parts, Technical Consultation, and Factory Service. Address all correspondence to:

HEATH COMPANY
Benton Harbor, Michigan 49022

For prompt service, use a separate letter for each department you write to.

Replacement parts and repair service are also available at your nearest Authorized Service Center or Heath Electronic Center. These Centers are listed in your Heath Catalog.

REPLACEMENT PARTS

If a replacement part is needed, please include the following information in your letter:

1. Part number and description.
2. Model Number and Series Number of the equipment.

If your equipment is in the Warranty period, add:

3. Date of purchase.
4. Nature of defect.

Heath Company will fill your order promptly. Please DO NOT RETURN PARTS unless they are requested. Parts that are damaged through carelessness or misuse by the customer will not be replaced without cost.

TECHNICAL CONSULTATION

You can write to our Technical Consultants for help with any Heath equipment, or for answers to any questions about the use of this equipment.

The completeness and accuracy of the advice mailed back to you depends entirely on the information in your letter. Be sure to include:

1. The Model Number and Series Number of the equipment (on blue and white identification label).
2. Date of purchase.
3. An exact description of the difficulty. Include switch positions, connections to other units, operating procedures, voltage reading, and any other information you think might be helpful.
4. List everything you have done in attempting to correct the difficulty.

FACTORY SERVICE

If you do not have qualified repair services at your disposal, you can return your equipment to the Heath Company Service Department to have it repaired for a minimum service fee. (Equipment that has been modified will not be accepted for repair.) Refer to Shipping Instructions for details on how to package and ship the equipment.

To be eligible for replacement parts under the terms of the Warranty, equipment returned for factory service must be accompanied by the invoice or the sales slip, or a copy of either. (If you send the original invoice or sales slip, it will be returned to you.)

SHIPPING INSTRUCTIONS

Check the equipment to see that all parts are in place. Then, wrap the equipment in heavy paper. Place the equipment in a strong carton, and put at least three inches of resilient packing material (shredded paper, excelsior, etc.) on all sides between the equipment and the carton.

Seal the carton with gummed paper tape and tie it with a strong cord. Ship it by prepaid Express or insured Parcel Post to:

HEATH COMPANY
Benton Harbor, Michigan 49022

Attach a letter, containing the following information to the outside of the carton:

1. Your name and return address.
2. Date of purchase.
3. A brief description of the difficulty.
4. Your authorization to ship the repaired unit back to you C.O.D. for the service and shipping charges, plus the cost of parts not covered by the Warranty.

WARRANTY

The Heath Company warrants that its factory-wired products (except any batteries supplied therewith) shall be free of defects in materials and workmanship under normal conditions of use and service. The obligation of Heath under this warranty is limited to repairing or replacing any such factory-wired product upon verification that it is defective in this manner. This obligation is further limited to such defective products for which Heath is notified of the defect within a period of one year from the original date of shipment of the product.

The obligation of Heath under this warranty with respect to transportation expenses is limited to the cost of shipping the repaired or replacement product to the buyer, provided such repair or replacement comes within the terms of this warranty.

The foregoing warranty extends only to the original buyer and is expressly in lieu of all other warranties, expressed or implied. The foregoing warranty is further in lieu of all other obligations or liabilities on the part of Heath and in no event shall the Heath Company be liable for any anticipated profits, consequential damages, loss of time or other losses incurred by the buyer in connection with the purchase, operation or use of the product.

This warranty applies only to Heath products sold and shipped to points within the continental United States and to APO and FPO shipments. Warranty replacements for Heath products sold or shipped outside the United States is on an f.o.b. factory basis. Contact the Heath authorized distributor in your country or write: Heath Company, International Division, Benton Harbor, Michigan, U.S.A.

HEATH COMPANY

All prices are subject to change without notice. The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

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